

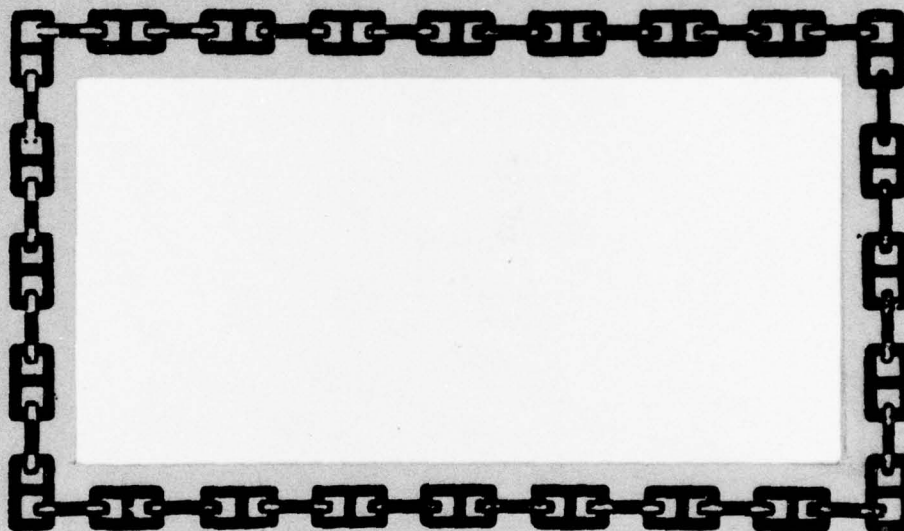
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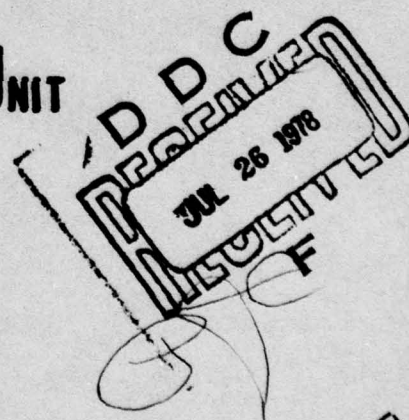


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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
Panama City, Florida 32407

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6 EVALUATION OF THE MARK 11 MOD 0 UBA
IN COLD WATER.

REPORT NO. 10-78

11 May 1978

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ABSTRACT

The MK 11 Mod 0 UBA was evaluated for its ability to efficiently absorb carbon dioxide during prolonged moderate work in cold water. In addition, thermal protection of the absorbent bed and the degree of inspired gas warming were analyzed. The results show that near the surface the apparatus can efficiently absorb CO₂ for prolonged periods in cold water, and that the absorbent bed is thermally protected. However, there was a virtual absence of inspired gas warming which may be a limiting factor for a diver at depth.

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20. → virtual absence of inspired gas warming which may be a limiting factor for a diver at depth.
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INTRODUCTION

The MK 11 Mod 0 UBA is an umbilical supplied, semi-closed underwater breathing apparatus which recirculates the diver's breathing gas, removes carbon dioxide produced by metabolic action of the body, and maintains inspired oxygen levels within physiologically safe limits. It is designed to provide diver life support to a depth of 850 FSW at temperatures as low as 28°F (-2.2°C). The system consists of the following equipment, each briefly discussed below:

(1) Diver Umbilical; (2) MK 11 Mod 0 UBA; (3) Thermal Protective Devices.

The diver umbilical consists of a hot water hose, gas supply hose, and an electrical cable. The hot water hose has a capability of supplying 2 gallons of water per minute at temperatures up to 110°F (44°C). The gas hose is 3/8" I.D. and has a pressure rating of 1050 psi. The electrical cable is a seven conductor cable which carries communication signals to and from the diver, as well as supplying power to the diver communications preamplifier, emergency gas switchover indicator, and PO₂ sensor amplifier.

The MK 11 Mod 0 UBA consists of a facemask, connecting hoses, and a backpack. Contained in the facemask is an

oral-nasal cup with microphone, a switchover indicator light, a face seal, and the second stage of a demand regulator. The backpack contains the breathing gas regulation, carbon dioxide absorbing canister, emergency gas supply, switchover sensing, and exhaust equipment. Breathing bags with an attitude sensitive exhaust valve fit against the diver's back. Contained in the inhalation bag is a PO_2 sensor and amplifier which transmits the PO_2 level to the support facility. Carbon dioxide absorbent is contained in a canister around which hot water from the diver umbilical circulates prior to being delivered to the divers hot water suit. While the UBA has four modes of operation, semi-closed or open circuit supplied by either the umbilical or emergency bottle, the umbilical supplied semi-closed mode is the primary mode and the only mode utilized in this study. Flow is controlled by varying the flow regulating orifice (sizes 6 - 13) and the supply gas overbottom pressure.

Thermal protection is provided by a hot water suit with an integral hood, and separate boots and gloves into which the hot water is exhausted. The hood of the hot water suit contains pockets to hold the communications earphones in place.

The purpose of this study was to evaluate the ability of the MK 11 Mod 0 UBA to efficiently absorb carbon dioxide during prolonged moderate work in cold water. In the course of the study, canister absorbent bed temperatures and inspired gas temperatures were also monitored to evaluate the thermal protection of the CO₂ absorbent and the degree of warming of the divers breathing gas.

METHODS

All tests were conducted in the Hydrospace Laboratory of the Naval Coastal Systems Center. Three experienced divers served as subjects. They all performed calisthenics and distance runs daily for three weeks prior to the test. In addition, they exercised on a bicycle pedal ergometer daily for one week prior to the tests.

Each diver wore the MK 11 Mod 0 UBA and NRV (Non Return Valve) hot water suit. Supply gas was stored in a salt water ice slurry at a temperature of 29°F (-1.67°C), and was delivered to the diver via 350 feet of MK 11 umbilical. The UBA had either a number 9 or a number 13 orifice, resulting in gas flows of 16.4 and 11.2 liters/minute respectively. The umbilical was coiled in the test pool which was maintained at a temperature of 29 - 34°F (-1.67 to 1.11°C). The supply gas used was 60% helium-40% oxygen. Carbon dioxide absorbents used were Baralyme, High Performance Sodasorb, and Type A Sodasorb. Two gallons per minute of hot water were delivered to each diver at

temperatures between 88 and 92°F (31.1-33.3°C). The overflow from the hot water suit was directed beyond the confines of the test pool via the non-return valve and an appropriately sized hose. This was done to prevent the warming of the working environment that would have occurred if hot water had been allowed to flow into the test pool.

Exercise sequences consisted of six-minute work periods, separated by four-minutes of rest, at a work rate of 50 watts on an especially modified pedal ergometer (James 1976) mounted on a frame approximately 4 feet underwater. Previous experience at NEDU has shown this sequence to approximate an average CO₂ production of 1.5 liters per minute. During one test, every fourth work cycle was performed at 150 watts, equivalent to a CO₂ production of 3.0 liters per minute. This was done to determine if high minute ventilation would result in CO₂ "blow by" secondary to inadequate gas residence time in the canister.

All measurements were made during the final minute of each exercise period. Gas samples were vented from the canister outlet through a 1/8" O.D. tube at an appropriate flow rate to an IR 864 CO₂ analyzer and to a mass spectrometer. In addition, multiple thermistor leads were mounted in the canister as depicted in Figure 1, and one thermistor was mounted just proximal to the oral-nasal cup. Throughout

portions of the experimental sequence recordings were obtained of the carbon dioxide fraction of the canister effluent, canister inlet and outlet gas temperatures, multiple absorbent bed temperatures, and the divers inspired gas temperatures. Except for one instance discussed below, exercise continued until either "canister breakthrough" was obtained, or seven hours duration was reached. Breakthrough was defined as that point in time at which the CO_2 in the canister effluent attained a value of 0.5% SEV (3.8 mmHg).

RESULTS

A total of eleven tests were completed as shown in Table 1. Only three canisters became exhausted. The first one occurred at 9 hours 49 minutes utilizing Baralyme and a number 9 orifice. The second one occurred at 7 hours with HP Sodasorb with a number 9 orifice. The last one occurred at 7 hours with HP Sodasorb and a number 13 orifice. One canister, using Barlyme and a number 9 orifice, functioned 12 hours and 21 minutes prior to the termination of the test, at which time canister effluent CO_2 was only 0.25% SEV (1.9 mmHg). In the one CO_2 "blow by" test, canister effluent CO_2 failed to exceed 0.3% SEV (2.3 mmHg) during severe work loads at the end of four hours. In all other tests, canister effluent CO_2 failed to reach 0.5% SEV by the end of 7 hours.

Figure 2 graphically depicts diver breathing gas temperatures. It can be seen that the gas was warmed as it passed through the canister, and exited at temperatures of up to 82°F (27.8°C). Cooling occurred, however, prior to reaching the divers' oral-nasal cup, with mean inspired gas temperatures ranging between 31 and 36°F (-.56 to 2.2°C). Inspired gas temperatures all were within 2 - 4°F (1.1 - 2.2°C) of ambient.

Figure 3 depicts multiple canister bed temperatures versus time. As can be seen, the mean outer bed temperatures were lower than the mean mid-bed temperatures at all times during the tests except for the initial hour. Mean center inlet temperature fell from 113°F (45°C) at one hour to 90°F (32.2°C) at 7 hours. Mean outer inlet temperatures fell from 77°F (25°C) at one hour to 72°F (22.2°C) at 7 hours. Mean center mid-bed temperature was 108°F (42.2°C) at one hour, increased to 113°F (45°C) at 2 hours, and remained relatively constant around 110°F (43.3°C) until 7 hours at which time it dropped to 102°F (38.9°C). There was a terminal rise in mean outer mid-bed temperature at 10 hours to 109°F (42.8°C) that remained until the end of the test. Mean outer mid-bed temperatures began around 90°F (32.2°C) and decreased to 78°F (25.6°C) at 8 hours, following which there was a terminal rise to 82-83°F (28°C). The mean center outlet bed temperature was 82 °F (27.8°C) at one hour, rapidly rose

to 109°F (42.8°C) at 6 hours, and remained near 110°F (43.3°C) the remainder of the study. Mean outer outlet bed temperature was 79°F (26.4°C) at one hour and slowly rose to 87°F (30.6°C) at 7 hours, persisting until 10 hours at which time there was a terminal drop to 82-83°F (28°C).

DISCUSSION

The results clearly demonstrate that in a shallow test pool the MK 11 Mod 0 UBA can efficiently absorb carbon dioxide during prolonged moderate work in cold water utilizing either Baralyme or Sodasorb. At no time did canister breakthrough occur in less than seven hours, and in view of the four hour limit presently imposed on the MK 11 Mod 0 UBA, this represents a significant margin of safety with respect to carbon dioxide absorption.

Analysis of the data on absorbent bed temperatures indicates that the thermal protection of the canister in cold water is excellent. At no time during the tests did any portion of the bed drop below 70°F (21.1°C), and the mean bed temperature for all locations tested was $92^{\circ} \pm 14^{\circ}\text{F}$ ($33.3 \pm 8^{\circ}\text{C}$). As expected, center bed temperatures were warmer than outer bed temperatures. The data also revealed that the pattern of temperature changes within the bed was consistent with the pattern of CO₂ absorption one might

anticipate. As CO_2 passes into a canister, the majority should be absorbed by the first portion of the absorbent bed encountered. Since CO_2 absorption is an exothermic reaction, one would expect to find the highest temperatures in that part of the bed doing the most absorption. This is supported by the finding that at one hour the mean center inlet bed temperature was the highest recorded. As the inlet absorbent slowly becomes chemically exhausted, the temperature should fall, as was the case. The mean mid-bed temperatures were next to rise as CO_2 absorption increased in that area. Mean temperatures in the mid-bed declined in the latter phases of the study at the same time that mean outlet bed temperatures rose. In general, mean outlet bed temperatures exceeded mean mid-bed temperatures between the sixth and seventh hours of the study. Since two breakthroughs were recorded at 7 hours, it was initially felt that in this study the fall in mid-bed temperatures below outlet bed temperatures might have been a useful parameter to follow in terms of predicting canister breakthrough. However, analysis of all data reveals there was no significant correlation between this temperature "crossover" and breakthrough. In fact, this crossover occurred between the sixth and seventh hours in the canister that lasted 12 hours 21 minutes, and failed to occur in the canister that broke through at 9 hours 49 minutes.

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The most significant finding of this study, while not unexpected, was the virtual lack of warming of the diver's inspired gas. As can be seen in Figure 2, in spite of gas warming within the absorbent bed the combination of cold supply gas and exposure of the inhalation bag to cold water led to inspired gas temperatures that differed little from ambient. While all the divers in this study reported being thermally comfortable, it must be borne in mind that the present study was conducted near the surface. At depth, breathing gas at ambient temperatures is quite a different matter, and could easily lead to insipient total body hypothermia, resulting in shivering, labored breathing with increased tracheo-bronchial secretions, mental confusion, and decreased physical performance. If carried to an extreme, it could result in death. It is vital, therefore, to evaluate the MK 11 Mod 0 at depth to determine whether or not this situation will develop. If it does, it will then be important to initiate measures to warm the inspired gas to ensure diver safety.

SUMMARY

The present study clearly demonstrates that near the surface the MK 11 Mod 0 UBA can efficiently absorb CO_2 during prolonged moderate work in cold water. However, it also reveals the absence of significant inspired gas warming. Since cold gas breathing may be hazardous under conditions of increased gas density, the MK 11 Mod 0 UBA should be evaluated at depth to determine the need for inspired gas warming.

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TABLE 1

Results of CO₂ Absorbent Studies With The MK 11 Mod 0 UBA

| ABSORBENT | ORIFICE SIZE | TEST | DID BREAKTHROUGH OCCUR | TIME TO BREAKTHROUGH, OR ELAPSED TIME AT TERMINATION OF TEST |
|-----------------|--------------|----------|---------------------------|--|
| Baralyme | 9 | Duration | No | 12:21 |
| Baralyme | 9 | Duration | Yes | 9:49 |
| Baralyme | 9 | Duration | No | 7:00 |
| Baralyme | 13 | Duration | No | 4:00 |
| Baralyme | 13 | Duration | No | 7:00 |
| Baralyme | 9 | Blow By | No | 7:00 |
| HP Sodasorb | 9 | Duration | Yes | 7:00 |
| HP Sodasorb | 9 | Duration | No | 7:00 |
| HP Sodasorb | 13 | Duration | No | 7:00 |
| HP Sodasorb | 13 | Duration | Yes | 7:00 |
| Type A Sodasorb | 9 | Duration | No | 7:00 |

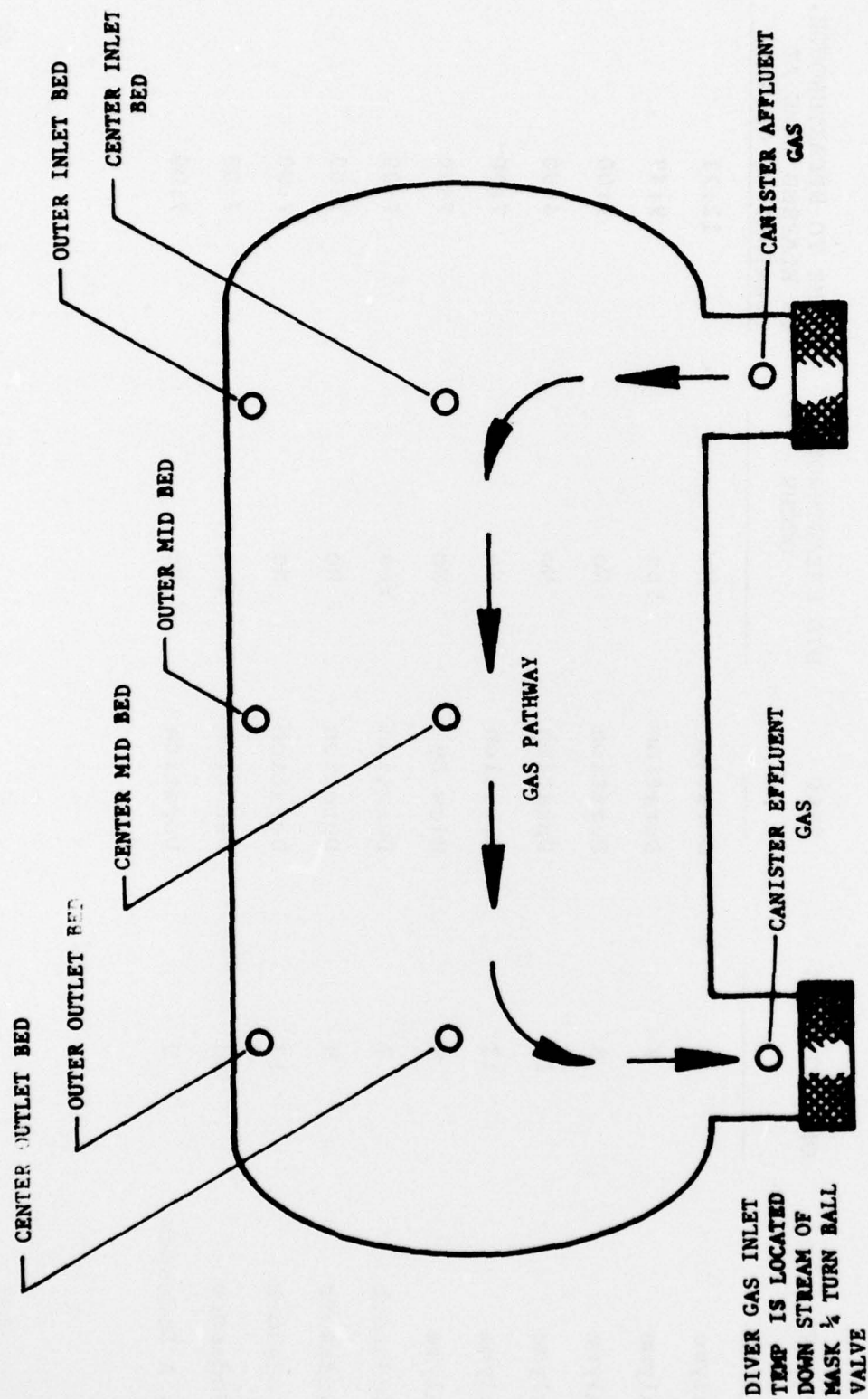


FIGURE 1. LONGITUDINAL SECTION THROUGH THE MIDDLE OF THE MK 11 MOD 0
UBA CANISTER DEPICTING LOCATION OF THERMISTOR LEADS

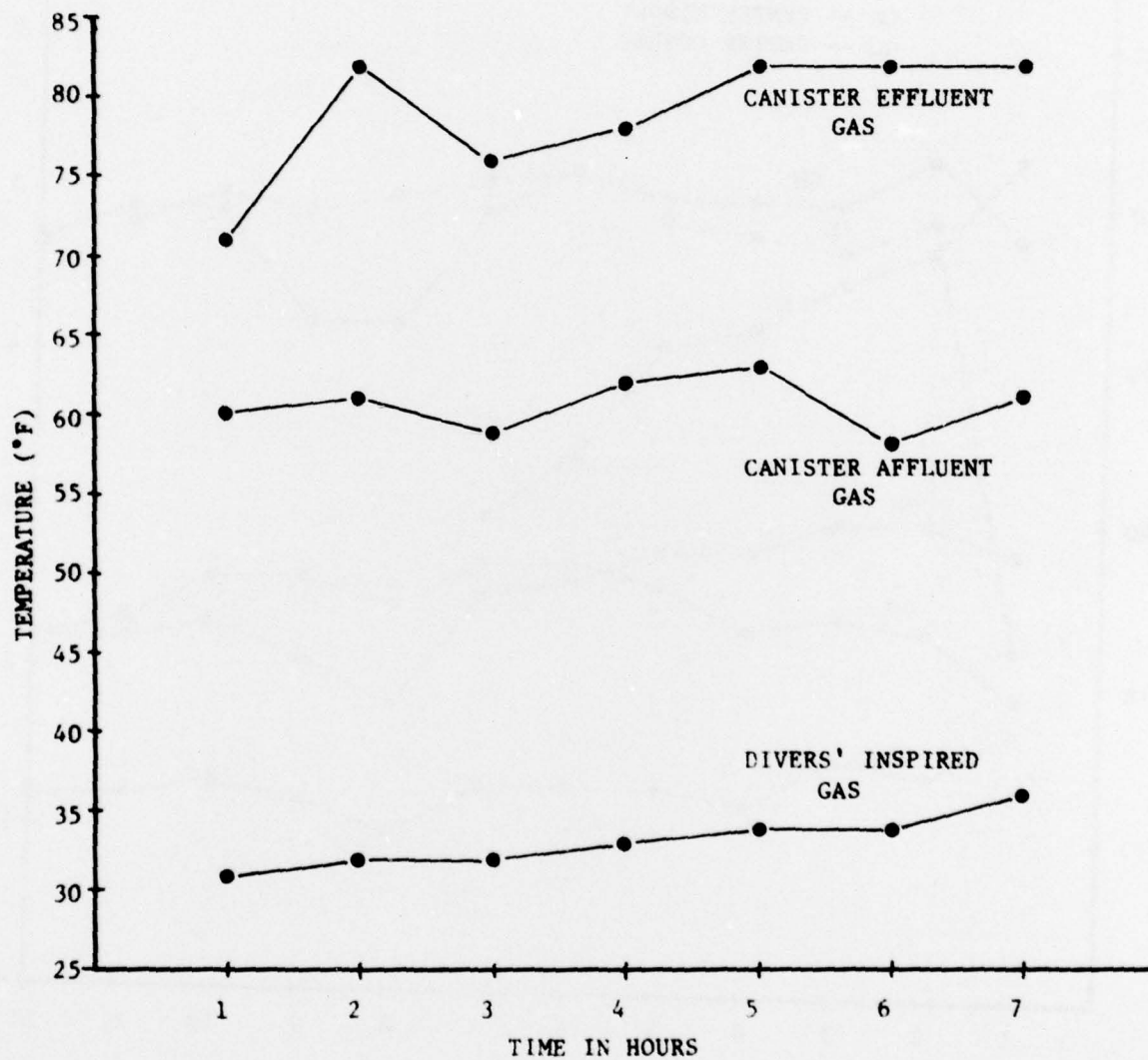


FIGURE 2. CANISTER EFFLUENT, AFFLUENT, AND DIVERS' INSPIRED GAS TEMPERATURES VERSUS TIME FOR MK 11 MOD 0 UBA - MEAN OF ALL TESTS. WATER TEMPERATURE 29-34° F

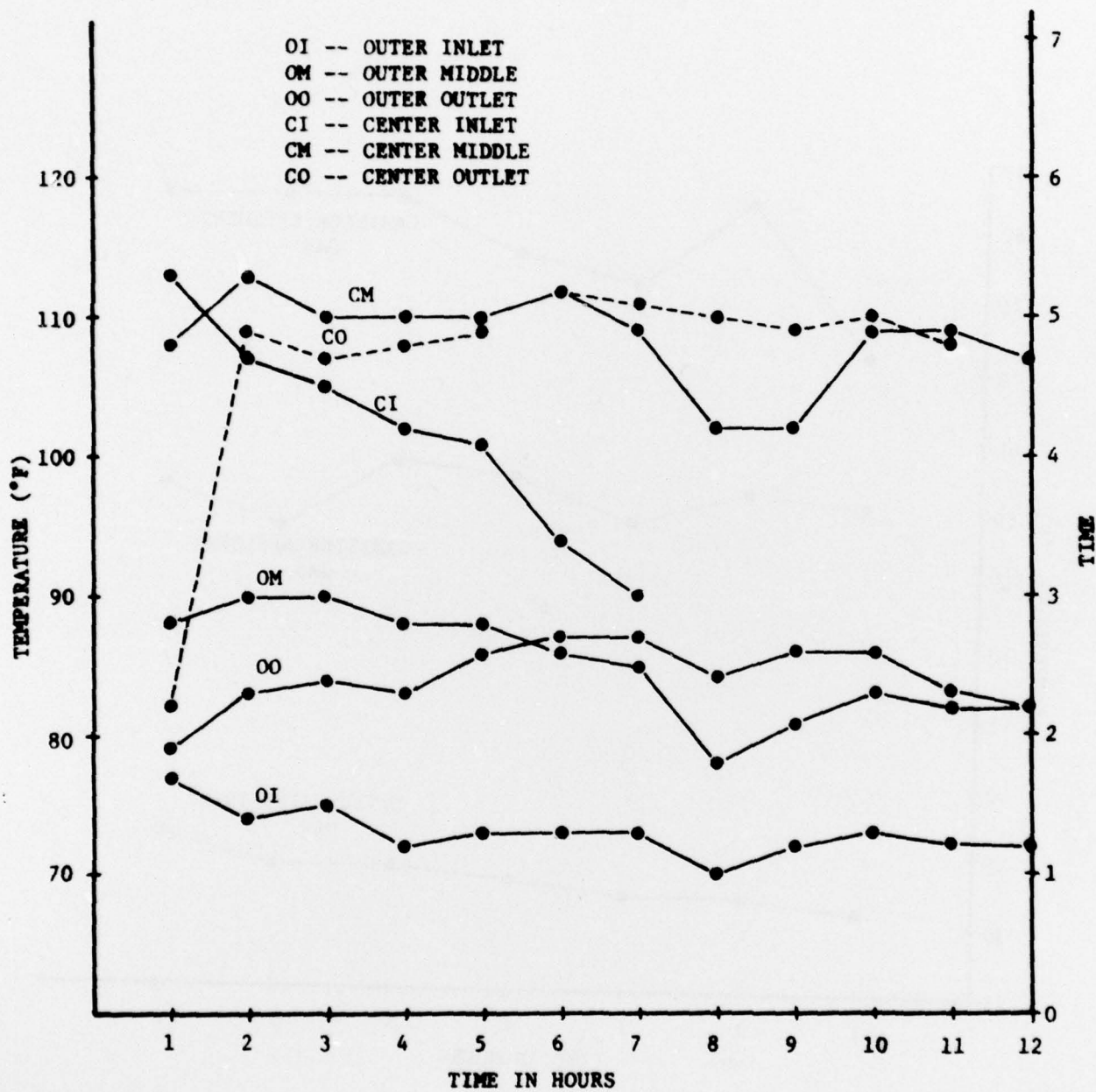


FIGURE 3. ABSORBENT BED TEMPERATURES VERSUS TIME FOR MK 11
MOD 0 UBA - MEAN OF ALL TESTS. WATER TEMPERATURE 29-34° F